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Alfalfa as an Alternative to Bermudagrass for Pastured Stocker Cattle Systems in the Southern USA

K. A. Cassida,* C. B. Stewart, V. A. Haby, and S. A. Gunter

ABSTRACT

Alfalfa (*Medicago sativa* L.) may support better stocker calf gains than common bermudagrass [*Cynodon dactylis* (L.) Pers.] in the southern USA. Yearling heifers (*Bos taurus* × *B. indicus*) grazed each type of pasture for 2 yr on a Coastal Plain soil in southwest Arkansas. Alfalfa stand counts declined linearly with time after planting. Spring forage mass was greater for alfalfa than bermudagrass, but summer dormancy of alfalfa resulted in a summer forage mass advantage for bermudagrass. Bermudagrass provided a longer grazing season (115–168 d for bermudagrass vs. 66–156 d for alfalfa, $P < 0.01$), more animal grazing days (1040–1452 vs. 594–1221 d, $P < 0.01$), and fewer grazing interruptions than alfalfa. Average daily gain (ADG, 462 vs. 319 g d^{-1}, $P < 0.05$) and total liveweight gain (664 vs. 447 kg ha^{-1}, $P < 0.05$) were greater for alfalfa than bermudagrass in Year 2. In both years, heifers grazing alfalfa made the same amount of liveweight gain in less time than heifers grazing bermudagrass. The bermudagrass system had a negative net return across the trial period. Net return for the alfalfa system was dependent on the value of harvested hay. When alfalfa hay value reached \$95 Mg^{-1} of dry matter (DM), net return was greater for the alfalfa system than for the bermudagrass system (\$59 vs. \$−148 ha^{-1}, $P < 0.05$). On a Coastal Plain soil, renovation of common bermudagrass to alfalfa pasture can be economically feasible under a dual stocker/hay production system.

New alfalfa varieties with improved grazing tolerance (Counce et al., 1984; Smith et al., 1989) have increased interest in alfalfa for pasture throughout the USA, including the southern regions. Bermudagrass is a typical summer pasture in the southern USA, but performance of stocker cattle often is poor on this forage during hot, dry, midsummer weather (Duble et al., 1971; Utley et al., 1974; Greene et al., 1990). This has been attributed to reduced forage growth and nutritive value late in the season and increased maintenance energy requirements of heavier cattle (Hill et al., 2001). Alfalfa was more drought tolerant than bermudagrass when grown in a mixture with Coastal bermudagrass on a Coastal Plain soil with slight acidity in the subsoil to 1.2 m (Haby et al., 1999), and therefore alfalfa may be able to sustain greater cattle gains during summer dry periods. Under ideal conditions, stocker cattle grazing alfalfa had ADG up to 1500 g d^{-1} and liveweight production up to 1946 kg ha^{-1} (Popp et al., 2000), but ADG (881 g d^{-1}) and liveweight gain (556 kg ha^{-1}) have been lower in the Coastal Plains region (Hoveland et al., 1988; Bates et al., 1996). By comparison, cattle grazing hybrid bermudagrass pastures in the Coastal Plains region had ADG up to 940 g d^{-1} (Conrad et al., 1981) and liveweight gains up to 1260 kg ha^{-1} (Greene et al., 1990). Common bermudagrass typically yields less than hybrids in hay trials (Hill et al., 2001) and might be expected to produce lower animal gains as well. Common is the prevalent bermudagrass type in most unimproved pastures (Fribourg et al., 1979), probably because of the convenience of establishment from seed plus good persistence under extensive pasture management.

Two major drawbacks to increased use of alfalfa on Coastal Plain soils are poor hay-drying weather and poor stand persistence related to subsoil acidity, low soil fertility, poor drainage (Haby et al., 1997, 1999), and high pest and disease pressures (Melton et al., 1988; Hoveland et al., 1996b). Grazing alfalfa offers a solution to the hay-drying problem, and Haby et al. (1997) showed that fertility and pH limitations of Coastal Plains soils can be managed and alfalfa grown with water tables as high as 45 cm below the soil surface. Grazing-tolerant alfalfa varieties have persisted for 2 (Bouton and Gates, 2003) to 3 (Counce et al., 1984) yr under grazing in Georgia.

Renovation of common bermudagrass pastures to alfalfa may present a useful production system to producers if returns can cover cost of alfalfa establishment and maintenance. We compared intensive management of common bermudagrass pastures against their renovation to alfalfa pasture for stocker cattle on a Coastal Plain soil. Our objectives were to compare forage mass, forage quality, stocker calf performance, and profitability of the two systems in the hot, humid southeastern USA.

MATERIALS AND METHODS

Pasture Establishment

The trial was conducted on an Ora fine sandy loam (fine-loamy, siliceous, semiactive, thermic Typic Fragiudults) in Hope, AR (33°40′ N, 93°35′ W, 107 m above sea level). Four 0.81-ha common bermudagrass pastures were renovated to alfalfa. Initial soil pH and Al concentrations in alfalfa pastures were 6.1 and 0 mg kg^{-1} at 0 to 15 cm in the soil profile, 6.5 and 0.6 mg kg^{-1} at 15 to 30 cm, 5.7 and 0.7 mg kg^{-1} at 30 to 61 cm, 5.1 and 6.4 mg kg^{-1} at 61 to 91 cm, and 4.9 and 9.7 mg kg^{-1} at 91 to 122 cm. Lime was applied in June at 5400 kg ha^{-1} to

Abbreviations: ADF, acid detergent fiber; ADG, average daily gain; a.e., acid equivalent; CP, crude protein; DM, dry matter; NDF, neutral detergent fiber.

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neutralize topsoil acidity, and gypsum was applied in July at 9000 kg ha^{-1} to ameliorate Al toxicity in the subsoil (Sumner, 1995). Alfalfa pastures were fertilized with 10 kg P, 63 kg K, 49 kg S, 25 kg Mg, and 4.2 kg B ha^{-1} based on soil analysis and recommendations of Haby et al. (1997) for Coastal Plain soils. Existing forage was killed by application of glyphosate (isopropylamine salt of N-[phosphonomethyl]glycine) at 3.68 kg acid equivalent (a.e.) ha^{-1} in June, and pastures were disked to 15-cm depth four times between 15 June and 15 September to incorporate fertilizer and soil amendments, break up the sod, and control weeds. After the final disking, soil was smoothed, cultipacked, and left fallow for 1 mo before planting. 'Graze-King' alfalfa was inoculated with *Rhizobium meliloti* and drilled 0.6-cm deep at 22 kg ha^{-1} of pure live seed and 15-cm row spacing on 21 Oct. 1999. Glyphosate was applied at 0.92 kg a.e. ha^{-1} immediately after planting to control emerging weed seedlings. Alfalfa pastures were cut for hay (5-cm stubble height) on 18 Apr. and 23 May 2000 to allow good seedling root development before grazing. Four 0.81-ha pastures estimated to consist of at least 95% of ground cover as common bermudagrass were grazed by beef cow-calf pairs while alfalfa treatments were being established. A summary of management inputs required for maintenance of alfalfa and bermudagrass pastures throughout the trial is presented in Table 1. Bermudagrass never produced enough biomass to warrant hay cutting outside of the grazing periods. Pesticides and top-clipping were employed for control of buttercup (*Ranunculus* spp.), spiny pigweed (*Amaranthus spinosus* L.), horsenettle (*Solanum carolinense* L.), and three-cornered alfalfa hopper [*Spissistilus festinus* (Say)].

Grazing Management

Pastures were grazed by preconditioned heifer calves of approximately 75% *Bos taurus* × 25% *B. indicus* breeding. All animal protocols were approved by the University of Arkansas Animal Care and Use Committee. Heifers were dewormed and implanted with growth promotants (testosterone propionate at 200 mg and estradiol benzoate at 20 mg) in February and June each year. Water and salt were available to heifers at all times from an access lane in each pasture. Heifers grazing alfalfa pastures had access to poloxalene blocks (PM Ag Products, Homewood, IL) to prevent bloat. Put-and-take stocking was used with six tester heifers permanently assigned to each pasture and extra grazer heifers added (put) or removed (taken) when needed to meet target grazing criteria. Alfalfa was grazed from 31 May to 14 Aug. 2000 and 20 Mar. to 22 Aug. 2001, and bermudagrass was grazed from 31 May to 21 Sept. 2000 and 12 Apr. to 26 Sept. 2001. To initiate staggered regrowth for rotational stocking, heifers were given access to the entire 0.81-ha pasture when herbage was approximately 20 cm tall for alfalfa and 7.5 cm tall for bermudagrass, and the accessible area was then reduced by enclosing successive 0.10-ha paddocks with electric fencing at 3- to 4-d intervals. Rotational stocking of both treatments began on 30 June 2000 and 9 May 2001, and ceased when pasture growth slowed (1 Sept. 2000 and 18 Sept. 2001). After the latter dates, heifers were allowed access to the entire pasture to better use the remaining forage. Target criteria for stocking alfalfa pastures were: (i) to graze paddocks to not less than 2.5-cm stubble height in not more than 7 d in 2000 or 3 d in 2001, (ii) to allow 28 to 45 d between grazings (Hoveland et al., 1996a), and (iii) to initiate grazing of alfalfa no later than one-tenth bloom. Target criteria for bermudagrass pastures were: (i) to use 50% of the available forage in each paddock in not more than 7 d and (ii) to allow 21 to 28 d regrowth between grazings. When grazing was not possible because of wet weather, pesticide withdrawal periods, or lack of forage, heifers were kept in a sacrifice paddock and fed bermudagrass hay free choice plus 3 kg heifer^{-1} d^{-1} of a 150 g crude protein (CP) kg^{-1} commercial supplement. Heifers were weighed at monthly intervals as well as when stocking rates were adjusted. To weight liveweight gain per hectare for varying ADG, stocking rates, and weigh period lengths over the season, gain per hectare per day was calculated as the product of ADG of tester animals and the total number of animals per hectare (testers plus grazers) on that day, and then summed over the reported measurement period.

Forage Quantity and Quality

Alfalfa stand density was measured in May 2000, March 2001, and October 2001 by counting crowns and stems from six randomly-selected 0.093-m^2 quadrats in each pasture. Forage mass and quality were measured weekly from a new paddock immediately before animals entered it. Forage quality samples were hand-clipped from three randomly-placed quadrats (sized 0.093 m^2 before 2 Aug. 2000 and 0.25 m^2 thereafter) and composited within pasture and date. The sampled stubble height of 2.5 cm was selected to represent the total forage mass in the potentially grazed horizon and was based on the lowest height to which cattle typically graze common bermudagrass. In 2000, forage mass in bermudagrass pastures was measured at 24 locations per paddock using a 30.5 by 30.5-cm rising plate which was calibrated via double sampling approximately every 2 wk (average $r^2 = 0.81$). Accuracy of the rising plate method was unacceptable for alfalfa pastures ($r^2 < 0.70$), so mass of alfalfa was determined by weighing the quadrat samples collected for forage quality. In 2001, forage mass was measured from the clipped quadrat samples for both treatments. Alfalfa samples were hand-sorted to determine the proportions of alfalfa and weeds. The unpalatable species spiny pigweed and

Table 1. Summary of inputs required for maintenance of alfalfa and bermudagrass pastures for 2 yr in Hope, AR.

	Pasture treatment	
Year/input	**Bermudagrass**	**Alfalfa**
2000		
Fertilizer†	168 kg N, 24 kg P, 120 kg K ha^{-1} (split across April, June, August)	74 kg K ha^{-1}
Herbicide‡	1.12 kg 2,4-D + 0.30 kg picloram a.e. ha^{-1} (July)	0.11 kg imazethapyr a.e. ha^{-1} (February)
Insecticide‡	none	1.12 kg carbaryl a.i. ha^{-1} (July)
2001		
Fertilizer	168 kg N, 186 kg K ha^{-1} (split equally across April, May, June)	152 kg K, 48 kg P, 4.2 kg B ha^{-1} (split equally across March, September)
Herbicide	0.92 kg glyphosate a.e. ha^{-1} (February) 1.12 kg 2,4-D + 0.30 kg picloram a.e. ha^{-1} (May)	0.11 kg imazethapyr a.e. ha^{-1} (July)
Insecticide	none	1.12 kg carbaryl a.i. ha^{-1} (July)

† Fertilizer applications based on Chapman (1998) for bermudagrass and Haby et al. (1997) for alfalfa.
‡ 2,4-D (triisopropanolamine salt of 2,4-dichlorophenoxyacetic acid), picloram (triisopropanolamine salt of 4-amino-3,5,6-trichloropicolinic acid), imazethapyr (ammonium salt of imazethapyr [±]-2-[4,5-dihydro-4-methyl-4-[1-methylethyl]-5-oxo-1*H*-imidazol-2-yl]-5-ethyl-3-pyridinecarboxlic acid); carbaryl (1-napthyl *N*-methylcarbamate); glyphosate (isopropylamine salt of *N*-[phosphonomethyl]glycine).

horsenettle were not included in forage quality samples and forage mass estimates. Forage allowance per heifer per day was calculated as forage mass at the beginning of the grazing period divided by paddock size, number of heifers in the paddock, and number of days the paddock was occupied.

All forage quality samples were dried at 55°C, ground to pass a 2-mm screen, and scanned across 1100 to 2500 nm on a Foss Model 3700 scanning monochromator equipped with a sample transport module (Foss North America, Inc., Eden Prairie, MN). Samples for calibration sets (alfalfa, $n = 96$; bermudagrass, $n = 103$) were selected using WinISI software (Version 1.5, Infrasoft International, Port Matilda, PA). Selected samples were analyzed sequentially for neutral and acid detergent fiber (NDF, ADF) using a Model 200 Fiber Analyzer (Ankom Technology, Fairport, NY). Amylase and sodium sulfite were not used in detergent fiber analyses. Total N concentration was determined by combustion (LECO model FP428, LECO Corp., St. Joseph, MI), and CP was calculated as N multiplied by 6.25 (AOAC, 2003; Method 990.03).

Economic Analysis

Economic feasibility of the two systems was compared using a partial budget approach. Only variables that were directly dependent on forage system were considered; fixed farm costs were considered to be equivalent across treatments. Values budgeted for alfalfa establishment (\$825 ha^{-1}) and sward maintenance inputs for bermudagrass and alfalfa (\$656, \$588 ha^{-1}, respectively) during grazing years were based on actual costs for the purchased research inputs. Alfalfa forage mass in November 2001 after stocker cattle had been sold was credited as a hay cutting to facilitate the economic comparison. Production output prices were based on the average Oklahoma auction market price for good-to-excellent quality alfalfa hay during the trial period and on typical Arkansas prices for contract grazing of stocker cattle. The amount of hay used during supplementation periods was estimated as 3% of test heifer weight ha^{-1} multiplied by number of hay feeding days. Hay fed was valued at the average Oklahoma auction market price of good quality bermudagrass hay during the trial period. Hay prices were converted to a DM basis, assuming 900 g DM kg^{-1} of hay. Production cost of pastures, cattle and hay were summed across 2000 and 2001 and subtracted from corresponding income sums to obtain net returns for both the cattle and the cattle plus hay enterprises. Alfalfa establishment cost was then subtracted from the cattle plus hay net return to determine whether renovation to alfalfa paid for itself over the experimental period.

Statistical Analysis

Data were analyzed as a randomized complete block design with four replications using PROC MIXED in SAS (SAS Inst., 2001). Pasture was the experimental unit. Data failed the chi-square test for homogeneity of variance across years and were therefore analyzed and presented separately by year. Replication was designated as a random effect while forage treatment and time within grazing season were fixed. Time within grazing season was analyzed as a repeated measure using unstructured, autoregressive, and compound symmetry covariance models for both homogeneous and heterogeneous data structures. The model with the smallest value for Akaike's Information Criterion was selected as best fit (Littell et al., 1996). Seasonal patterns in forage quality during the rotational stocking period were evaluated by regressing forage quality components on week using PROC REG in SAS. Means across pasture replications were used in the regression analyses (Gomez and Gomez, 1984). Statistical significance was declared at $P < 0.05$ unless otherwise stated.

RESULTS

Weather was unusually dry for the region (Fig. 1) in the winter of 1999/2000, but fall/winter 2000/2001 was wet. Alfalfa crown and stem densities declined linearly over time (Fig. 2). The proportion of alfalfa in the forage mass (data not shown) was near 100% throughout 2000 and before rotation began in 2001, but averaged only 74% of the forage mass across the rotationally stocked period in 2001, with a low of 47% in mid-July. The balance of the forage mass was bermudagrass, annual ryegrass (*Lolium multiflorum* Lam.), and palatable weeds.

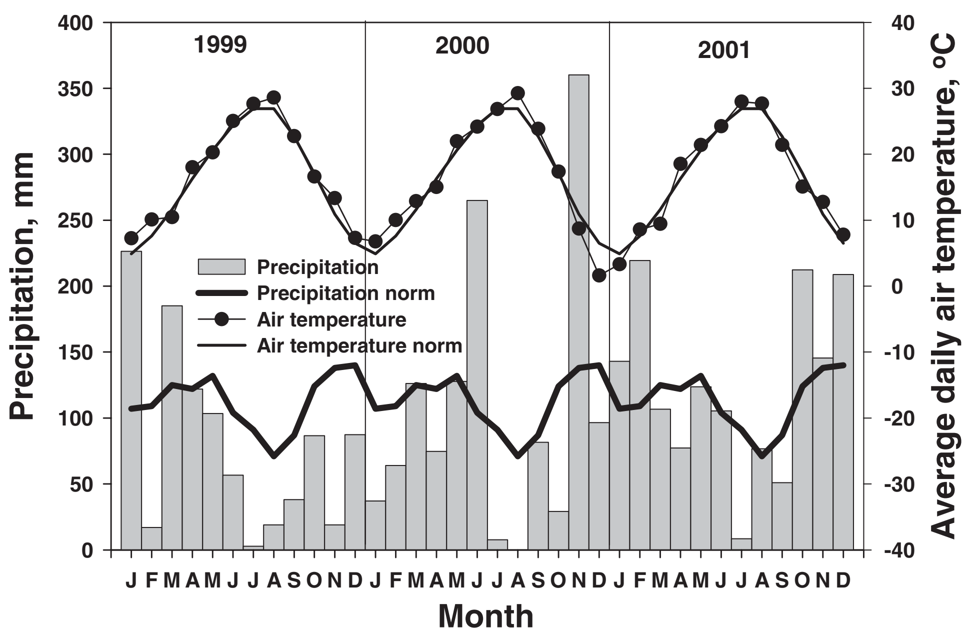

Fig. 1. Actual and normal precipitation and average and normal daily air temperature in Hope, AR, from 1999 to 2001.

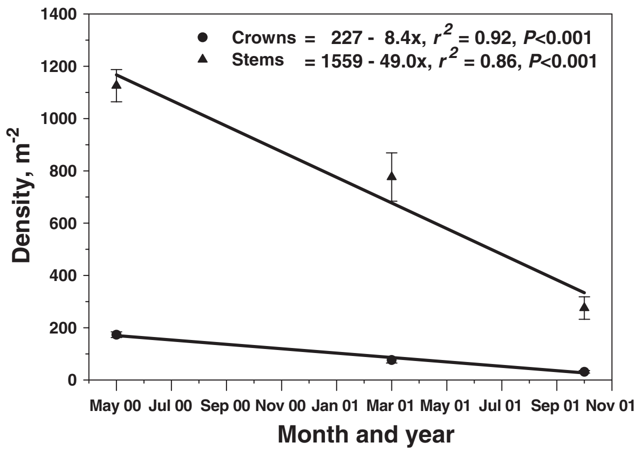

Fig. 2. Crown and stem density decline in alfalfa stands established in October 1999 and grazed during 2000 and 20001 in Hope, AR. Vertical lines are standard errors.

Forage mass and forage allowance (Fig. 3) were greater for bermudagrass than for alfalfa (3861 vs. 1694 kg mass ha^{-1}, 42 vs. 23 kg calf^{-1} d^{-1}) through most of the 2000 grazing period, with an interaction between treatment and time ($P < 0.001$) related primarily to variability in the magnitude of the difference. In 2001, a crossover interaction occurred between treatment and time ($P < 0.001$) in which forage mass and allowance were generally greater for alfalfa than for bermudagrass up to the initiation of rotational stocking during the week of 7 May, similar from 7 May to 1 July, and greater for bermudagrass thereafter. Alfalfa went dormant during August of both years, necessitating heifer removal from pastures due to lack of forage. Alfalfa broke summer dormancy when cool fall weather and rain arrived, but did not accumulate useable amounts of forage in fall 2000. In 2001, alfalfa pasture accumulated 6733 kg ha^{-1} of forage by 14 November.

Alfalfa was consistently the same or greater in CP and lower in NDF than bermudagrass throughout the trial (Fig. 4). Forage ADF levels were similar across treatments in 2000, but usually greater for alfalfa than bermudagrass in 2001. In 2000, interactions between forage treatment and time within grazing season for ADF and CP in both years ($P < 0.001$) were related to changing rank of treatments on individual dates. In 2001, interactions between treatment and time for all forage quality measures were primarily related to treatment differences in the rate of change over time (Fig. 4). In 2001, alfalfa forage quality increased across the early part of the grazing season while pastures were gradually being subdivided into rotation paddocks. During the rotational management period, alfalfa NDF and ADF increased while CP decreased linearly with time. With rotational management, bermudagrass pastures exhibited the same trends as alfalfa, but with a curvilinear pattern for fiber components. Bermudagrass CP decreased linearly over the season, with localized peaks corresponding to N fertilization events in May and June (Table 1).

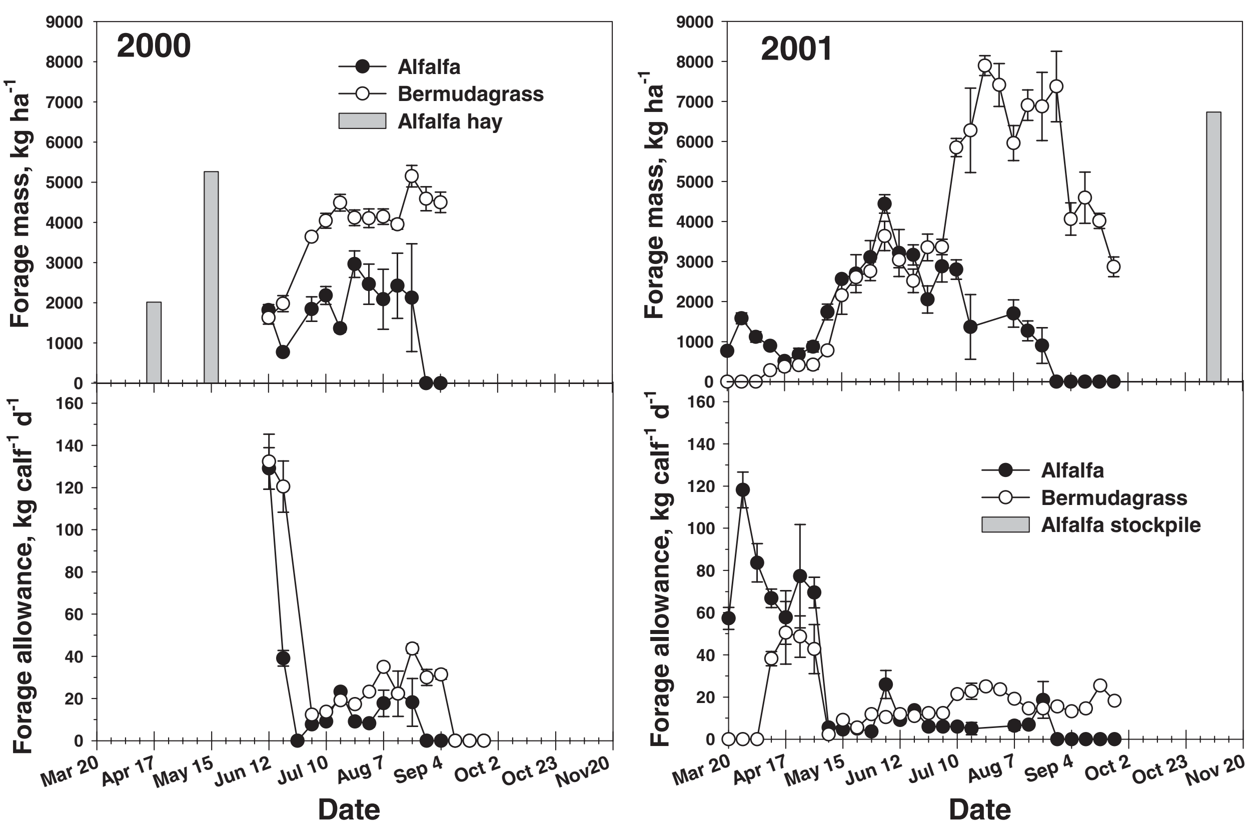

Fig. 3. Total forage mass and forage allowance per calf per day during the growing season for alfalfa and bermudagrass pastures in 2000 and 2001. Bars represent alfalfa hay yields in the spring 2000 and fall 2001. Vertical lines are standard errors.

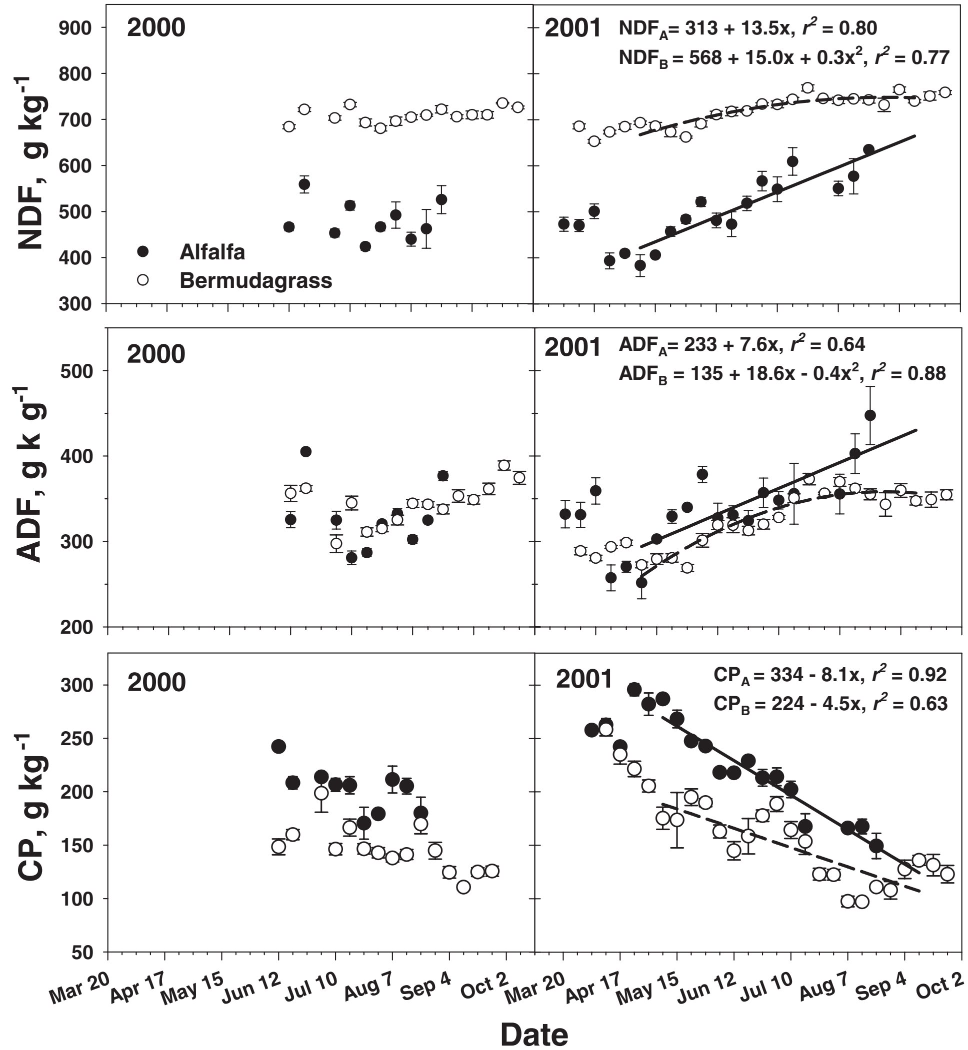

Fig. 4. Neutral and acid detergent fiber (NDF, ADF) and crude protein (CP) concentrations of alfalfa and bermudagrass pasture during the 2000 and 2001 grazing seasons in Hope, AR. The value of x in regressions was the number of weeks after 20 March. Each tick mark on the *x* axis represents 1 wk. Regressions for 2000 were nonsignificant. Regressions for 2001 were calculated using only data from the rotational stocking management period (30 June–18 September) and were all significant at $P < 0.001$. Vertical lines are standard errors.

Heifers were reluctant to consume alfalfa when it was first presented, but grazed it readily within approximately 1 wk. No heifers bloated at any time during the trial, nor was there mortality from any other cause on either treatment. For the short 2000 grazing season, there was no difference between alfalfa and bermudagrass forages for ADG, stocking rate (Table 2), final calf weight (299 vs. 309 kg, respectively), or total gain per hectare (396 vs. 394 kg ha^{-1}). For the 2001 grazing season, final calf weight (308 vs. 300 kg) and stocking rate (Table 2) were again unaffected by forage species, but ADG (Table 2) and gain per hectare (664 vs. 447 kg ha^{-1}, $P < 0.05$) were greater for heifers grazing alfalfa. Bermudagrass provided more total days on pasture, more grazing days, more animal grazing days, and fewer supplemental feeding days than alfalfa in both years (Table 2). In 2001, the bermudagrass grazing period was delayed by approximately 1 mo compared to the alfalfa grazing period. Figure 5 shows the pattern of heifer performance within grazing seasons. Heifers grazing alfalfa were heavier and had greater ADG than heifers grazing bermudagrass on 6 July 2000 and 9 May 2001, but body weights and ADG were similar between treatments on other weigh dates. Across years, cumulative liveweight gain was greater on alfalfa than bermudagrass for every weigh period except 7 Aug. 2001.

Alfalfa swards were more expensive to maintain than bermudagrass and had greater costs related to both animal and hay production (Table 3). Value of cattle gain tended ($P < 0.09$) to be greater for grazing alfalfa than for grazing bermudagrass. Value of alfalfa hay harvested was greater for alfalfa than for bermudagrass and had a large impact on system net returns. When only costs and income from cattle were considered, net returns were negative during 2000 to 2001 and did not differ across forage systems. Inclusion of alfalfa establishment costs into net return calculations for the cattle-only enterprise resulted greater net loss for grazing alfalfa than bermudagrass. The break-even value for hay harvested within the alfalfa system was \$91 Mg DM^{-1}, and when alfalfa hay

Table 2. End-of-season performance of yearling beef heifers and duration of grazing periods for bermudagrass and alfalfa pastures in 2000 and 2001 in Hope, AR.

Year/pasture	ADG†	Stocking rate	Duration of grazing periods‡ Total	Grazing	Hay fed	Animal grazing days
	$g\ d^{-1}$	$calves\ ha^{-1}$	d			$d\ ha^{-1}$
2000						
Bermudagrass	460	9.0	115	115	0	1040
Alfalfa	574	8.9	77	66	11	594
SE	49.4	0.06	3.0	3.0	0	29.7
$P < F$	NS	NS	**	**	**	**
2001						
Bermudagrass	319	8.6	168	168	0	1452
Alfalfa	462	9.3	156	125	31	1221
SE	37.8	0.21	1.6	2.1	0.5	48.9
$P < F$	*	NS	*	***	***	*

* $P < 0.05$.
** $P < 0.01$.
*** $P < 0.001$.
† All data shown as least square means. Weights are based on animal full body weights. ADG = average daily gain; NS = not significant.
‡ Grazing season: alfalfa = 30 May to 14 Aug. 2000 and 20 Mar. to 22 Aug. 2001; bermudagrass, 31 May to 21 Sept. 2000 and 12 Apr. to 26 Sept. 2001.

was valued at this price (Table 3), overall net return including establishment of the alfalfa cattle-plus-hay system did not differ from the bermudagrass system. At an alfalfa hay value of \$95 Mg DM^{-1}, the alfalfa system had greater net returns than the bermudagrass system (\$59 vs. \$−148 ha^{-1}, $P < 0.05$), and at an alfalfa hay value of \$66 Mg DM^{-1}, net returns were less for the alfalfa system than for the bermudagrass system (\$−348 vs. \$−148 ha^{-1}, $P < 0.05$).

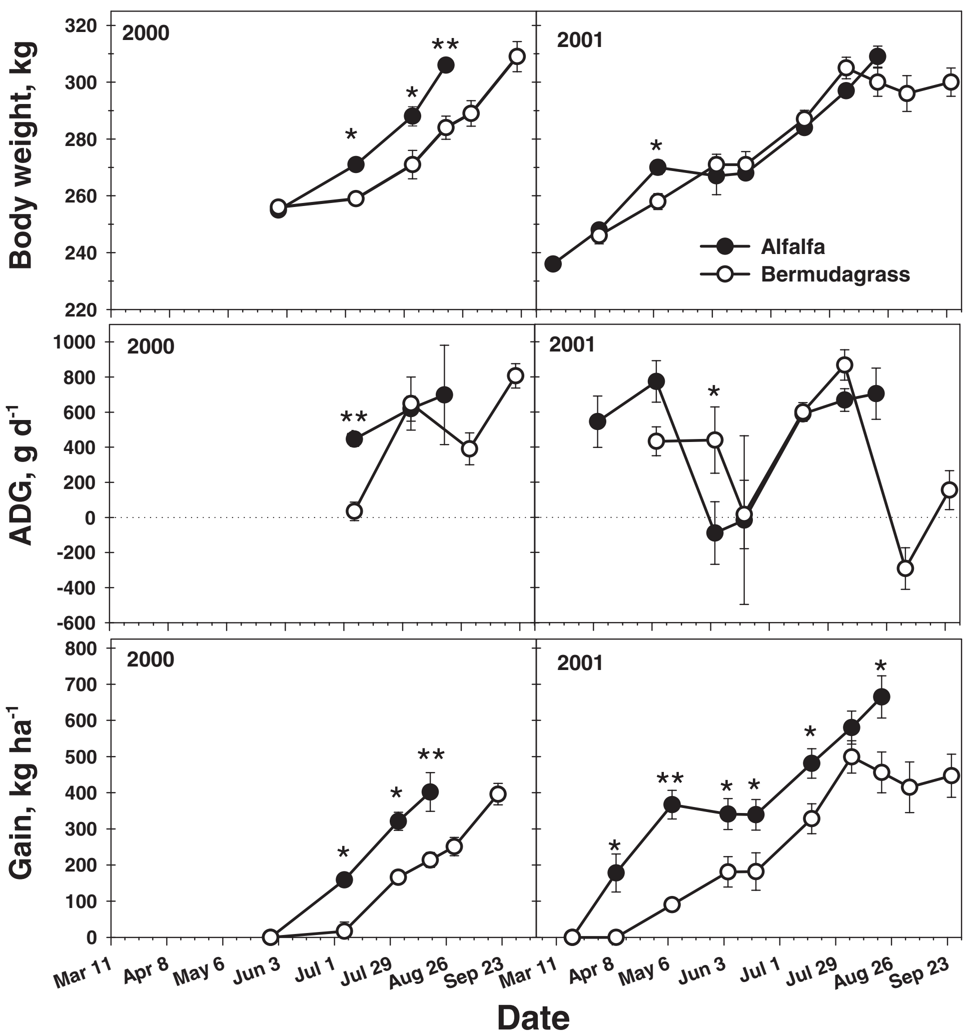

Fig. 5. Full body weight, average daily gain (ADG), and cumulative gain per hectare of yearling heifers grazing alfalfa and bermudagrass pastures during the 2000 and 2001 grazing seasons in Hope, AR. Vertical lines are standard errors. (*,**, *** $P < 0.05, 0.01, 0.001$, respectively for treatment comparison on a particular date.)

Table 3. Partial budget analysis of variable costs for bermudagrass- or alfalfa-based stocker cattle production systems in Hope, AR, from 1999 to 2001.

Cost	Pasture treatment: Bermuda	Pasture treatment: Alfalfa	SE	$P < F$
	$\$ ha^{-1}$			
Alfalfa establishment cost†, 1999	0	825	–	–
Sward maintenance cost, 2000 to 2001	656	588	–	–
Haying-related costs, 2000 to 2001	0	222	–	–
Cattle-related costs, 2000 to 2001	140	461	4.9	***
Total maintenance and production costs	796	1271	4.9	***
Income, cattle gain‡	648	817	57.4	0.09
Income, hay harvested§	0	1282	20.4	***
Total income, 2000 to 2001	648	2099	62.6	***
Net return for cattle, 2000 to 2001	−148	−232	53.9	NS
Net return for cattle less establishment costs	−148	−1057	53.9	***
Net return for cattle plus hay, 2000 to 2001	−148	828	58.8	***
Net return for cattle plus hay less establishment cost	−148	3	58.8	NS

*** $P < 0.001$.

† Costs that do not include SE or P values did not vary across replications within treatments. Sward maintenance costs included pesticide and fertilizer applications. All costs except supplemental hay and equipment operation were calculated as actual cost of inputs during the trial. Equipment operation cost for hay harvest was estimated at \$24.70 ha^{-1} per trip with three trips across pastures per hay cutting. Cattle-related costs included salt, poloxalene, grain, and supplemental hay (\$37 Mg DM^{-1}).

‡ Value of cattle gain was set at \$0.77 kg^{-1} based on regional contract grazing prices during the experiment.

§ Hay value was set at the break-even level of \$91 Mg DM^{-1}.

DISCUSSION

Alfalfa had greater early season forage mass than bermudagrass, but it went dormant in August each year at exactly the time we had hypothesized that its deep root system would give it a competitive advantage over more shallow-rooted bermudagrass. When alfalfa went dormant, it dropped its leaves and presented no useful stockpiled forage. The combination of an Ora soil typified by a fragipan, frequently saturated ground conditions, and minimally acceptable subsoil acidity and Al concentration may have contributed to a shallow root system (Joost and Hoveland, 1986; Scheaffer et al., 1988) that reduced alfalfa's ability to reach deep soil water during summer drought. Hoveland et al. (1988) also reported that the alfalfa grazing season can be truncated by summer drought in the southern USA.

Dry weather in the first winter was favorable for establishment of alfalfa, but stands thinned quickly. After 2 yr of grazing, both crown and stem densities were lower than previously reported for grazed alfalfa (Hoveland et al., 1988; Smith et al., 1989; Bouton and Gates, 2003). Alfalfa has produced acceptable cattle performance at plant densities as low as 10.8 crowns m^{-2} (Lacefield et al., 1996). We projected that our pastures would be below this density by the start date of a third grazing season if stand thinning were to continue at the linear rate measured during the first two seasons. This occurred despite use of rotational stocking as recommended for optimal survival of grazed alfalfa (Bouton and Gates, 2003). Rapid stand decline was likely related to frequently saturated soil conditions (Scheaffer et al., 1988).

In bermudagrass pastures, weeds were readily controlled with herbicides and insect pests were not observed. In contrast, pest control was the most challenging component of alfalfa management because it was difficult to time grazing around pesticide withdrawal periods. Alfalfa matured through the full bloom stage and began dropping leaves before the 28-d grazing withdrawal for the summer application of imazethpyr was complete, which led to a forage shortage during this time and necessitated supplemental feeding. The highly mobile nature of three-cornered alfalfa hopper necessitated applying insecticide to all pastures simultaneously instead of on a staggered schedule, thus necessitating alternative feed for the animals during the grazing withdrawal period. Carbaryl provided only temporary relief from this insect, which is a major pest of alfalfa in southern areas (Sorenson et al., 1988; Haby et al., 1997).

Patterns of forage availability followed expected trends for bermudagrass, which as a warm-season plant, should reach maximum growth later in the season than cool-season plants (Belesky et al., 2002). Bermudagrass pastures accumulated a large amount of standing biomass in summer, especially in 2001, because of regrowth from upper nodes on grazed stubble. Heifers largely refused to graze below this upper leafy layer, resulting in progressive accumulation of ungrazed stemmy material with each rotation. This was consistent with bermudagrass quality being highest in the upper canopy layers, but most of the forage mass being in the lower layers (Wilkinson et al., 1970). Stem accumulation might be remedied if grazing with stocker calves was followed by a grazing with adult cattle to use the stubble. The accumulated bermudagrass stubble did provide stockpiled, albeit low nutritive value, forage that maintained heifers through periods of slow growth in August.

During the rotational stocking periods in 2001, alfalfa forage allowance was often <10 kg $heifer^{-1}$ d^{-1}. The relatively lower forage allowance for alfalfa in 2001 compared to 2000 was the result of increased stocking densities used in an effort to graze alfalfa to the target stubble height. While heifers readily grazed alfalfa to the target height during the spring when stands were leafy and lush, they refused to eat stems in summer. Stem refusal encouraged alfalfa regrowth from stem as well as crown buds, a situation which can reduce alfalfa yields (Wolf and Blaser, 1981). Mowing exit paddocks was not a feasible solution because heifers trampled many of the stems flush to the ground. Stem refusal probably contributed to stand decline as well as affecting heifer performance. Belesky and Fedders (1997) reported that a 10-cm stubble resulted in lower yields, reduced crown density, and increased weed encroachment in 'Alfagraze' stands when compared to <2- or 5-cm stubbles.

In general, fluctuations in forage quality from week to week were less for bermudagrass than for alfalfa, and bermudagrass changed less in quality over the entire season. Alfalfa had consistently greater CP and lower NDF than bermudagrass, and often had less ADF than bermudagrass. Hoveland et al. (1988) reported a similar decline in alfalfa CP over the grazing season. Our CP concentrations were similar to those reported in Georgia (Hoveland et al., 1988) and Michigan (Schlegel et al., 2000b) at the beginning of the grazing season, but were less than in those studies at the end of the season. For bermudagrass, NDF was similar to reported ranges (Griffin and Watson, 1982; White and Hembry, 1985; Hill et al., 1993), but ADF concentrations were outside reported ranges for pastures (Griffin and Watson, 1982; White and Hembry, 1985) at both the high and low end of the range. Bermudagrass CP tended to be high relative to reported values (Griffin and Watson, 1982; White and Hembry, 1985; Hill et al., 1993; Aiken, 2002) in our pastures, a result that may be related to use of common instead of hybrid bermudagrass. Energy is more likely than CP to limit animal performance on alfalfa pasture (Van Keuren and Matches, 1988), a situation that may also occur with other pasture forages. The greater NDF concentration of bermudagrass suggested that its digestibility and thus energy value was less than that of alfalfa (Henderson and Robinson, 1982; Albrecht et al., 1987). Because of the greater forage allowance for most of the season on bermudagrass relative to alfalfa, bermudagrass heifers had greater potential to select diets that were of better quality than the total sward and thereby further reduce the impact of differences in sward quality between treatments.

For cattle grazing alfalfa, liveweight gain per hectare was similar but seasonal ADG was less than reported in Georgia (Hoveland et al., 1988; Bates et al., 1996). In a Michigan trial (Schlegel et al., 2000a) with stocking rates similar to this study, liveweight gain and ADG on alfalfa were also similar. Animal performance was relatively low in this study compared to other reports for steers grazing bermudagrass (Utley et al., 1974, 1981; White and Hembry, 1985; Greene et al., 1990; Conrad et al., 1981; Hill et al., 1993; Aiken, 2002). This was consistent with lower weight gains of heifers compared to steers and with use of common bermudagrass instead of a higher-yielding hybrid variety (Hill et al., 2001). Decreases in ADG on bermudagrass in August of both years are typical of the forage (Utley et al., 1974, 1981; Greene et al., 1990) and were likely a consequence of reduced forage quality, because forage allowance was greater in August than earlier in the season. The decrease in ADG for both treatments in late May to June 2001 coincided with the shift from continuous to rotational stocking management and its resultant decrease in forage allowance. This temporary depression in performance may indicate that those heifers were slow to adapt their grazing behavior to the relatively sudden change in forage availability.

An adequate economic return on investment is critical for adoption of pasture renovations. Once established, alfalfa swards cost less to maintain than bermudagrass swards (Table 3). The largest single yearly expense for alfalfa maintenance was weed control (\$259 ha^{-1}) and for bermudagrass was fertilizer (\$283 ha^{-1}). Grazing-related expenses were greater for alfalfa than bermudagrass because of the greater number of hay feeding days in the alfalfa treatment. Attainment of a positive net return for the alfalfa system was dependent on the value of the alfalfa hay harvested. Value of good to excellent quality alfalfa hay ranged from \$61 to \$152 Mg DM^{-1} in the region during the trial period (source: Grain Market News, Univ. Arkansas Coop. Ext. Serv., USDA, Univ. Arkansas, County Gov. cooperating), so a hay value meeting or exceeding the system break-even price of \$91 Mg DM^{-1} was attainable. Adjusting the hay value upward by only \$4 Mg DM^{-1} over the break-even value enabled the alfalfa system to show a significant positive net return over the bermudagrass system. While changing values for inputs and products will produce endlessly variable outcomes for this type of economic analysis, results nevertheless show that it is possible to return a profit in the Coastal Plains region by renovating common bermudagrass to alfalfa, even with only a 2-yr alfalfa stand life. The flexibility added to the system by hay harvest also might improve overall utilization and regrowth of forage by allowing an alternative harvest method for alfalfa when weather or pesticide applications interfere with timely grazing.

CONCLUSIONS

Established alfalfa was ready to graze about 1 mo earlier in spring than common bermudagrass and also provided more forage in fall, but bermudagrass provided more late-summer grazing. Summer weed and insect control in alfalfa was difficult to manage under grazing because alfalfa presented a very short window of opportunity when ready to graze. As a result, alfalfa had more interruptions in the grazing rotation that required an alternative source of feed for the cattle. Bermudagrass provided more calendar and animal grazing days than alfalfa, as well as an uninterrupted grazing period once heifers were turned onto pastures, but alfalfa pasture required fewer calendar days to make equal or better liveweight gains per hectare. This effect might be used to the advantage of cattle producers by shifting ownership dates for stockers earlier into the year and thus shifting cattle purchase and sale into periods where prices may be more favorable. Profitability of the alfalfa system was highly dependent on harvest of some forage as hay and on value of that hay. Hay harvest allowed the alfalfa system to show positive net returns over the bermudagrass system despite the high cost of alfalfa establishment. In the Coastal Plains region, renovation of common bermudagrass to alfalfa pasture is feasible, but dual stocker/hay production systems may provide more flexible management options for alfalfa than systems based on stocker cattle only.

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